



A comparative review on the impact of health misinformation on medication use and antimicrobial resistance: A narrative review

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Abstract

Background: Antimicrobial resistance (AMR) is among the most urgent global health challenges of the 21st century, causing approximately 1.14 million deaths each year¹ due to drug-resistant bacterial infections. Alongside this issue, the spread of health misinformation through digital and traditional media has exacerbated the misuse of medications worldwide.

Objective: To compile existing research on how misinformation related to medications affects drug use behaviours, thereby hastening the emergence and dissemination of antimicrobial resistance.

Methods: A narrative review was performed in accordance with SANRA guidelines. Searches were conducted in PubMed, Scopus, and Google Scholar (2015–2025) using terms such as “misinformation,” “antibiotics,” “antimicrobial resistance,” “self-medication,” and “social media.” The review included peer-reviewed articles, systematic reviews, and grey literature from WHO/CDC.

Key findings: Four main mechanisms were identified: (1) the persistent misconception that antibiotics can treat viral infections, with only 42.1% of the global population understanding that antibiotics do not work against viruses; (2) early discontinuation and dose reduction of antibiotics due to misinformation about the microbiome; (3) mistrust in vaccines leading to lower coverage and increased demand for antibiotics; and (4) distrust in diagnostics resulting in the use of broad-spectrum antibiotics empirically. Social media, especially TikTok, has amplified these false beliefs, with misinformation videos receiving 2.5 times more engagement³ than content based on evidence.

Conclusion: Health misinformation is a significant and modifiable factor driving inappropriate medication use and antimicrobial resistance. Immediate, multidisciplinary strategies—including digital pre-bunking, training for clinicians in communication, and regulation of platforms—are necessary to address this escalating threat.

Keywords: Health misinformation, antimicrobial resistance, medication adherence, self-medication, social media, public health, antibiotic stewardship

Introduction

Antimicrobial resistance (AMR) is frequently labelled as a silent pandemic with profound global impacts. A detailed global burden study featured in *The Lancet* (2024) projects that by 2050^[41], AMR could lead to 1.91 million deaths and be linked to 8.22 million deaths worldwide. Between 2025 and 2050, it is anticipated that around 39 million people will succumb directly to bacterial AMR. In hospital settings, over one-third of infections acquired are due to drug-resistant bacteria^[6], and patients with these resistant infections face a 58% higher adjusted mortality risk compared to those with treatable infections.

Metric	Value	Year/Source
Annual deaths due to drug-resistances	1.14 million	2024
Project annual AMR deaths by 2050	1.91 million	Lancet 2024
Total projected deaths (2025-2050) ^[41]	39 million	IHME
Increased mortality risk with resistant infections	58%	2025
Global population knowing antibiotics don't work vs viruses	42.1%	2025 meta-analysis
Misinformation video engagement advantage	2.5x more	AAP 2025

Health misinformation is defined as any health-related claim that is false, inaccurate, or misleading according to the prevailing scientific consensus.²³ It is crucial to distinguish between misinformation, which is unintentionally false, and disinformation, which is intentionally misleading, as both can have harmful effects. The COVID-19 pandemic vividly demonstrated how misinformation can rapidly spread across digital platforms, leading to harmful behaviours such as self-administration of ivermectin, vaccine hesitancy, and the replacement of evidence-based treatments with unproven alternatives. Medication use plays a pivotal role in controlling AMR, as inappropriate prescribing and consumption directly exert selective pressure on bacterial populations. Despite this, the specific link between medication-related misinformation and AMR has not been systematically integrated into resistance control frameworks. This narrative review seeks to: (1) identify the sources and channels of medication misinformation; (2) elucidate the behavioural mechanisms that lead to inappropriate drug use; (3) evaluate evidence for both direct and indirect impacts on AMR; (4) assess the economic and public health consequences; and (5) propose evidence-based strategies to counteract these issues.

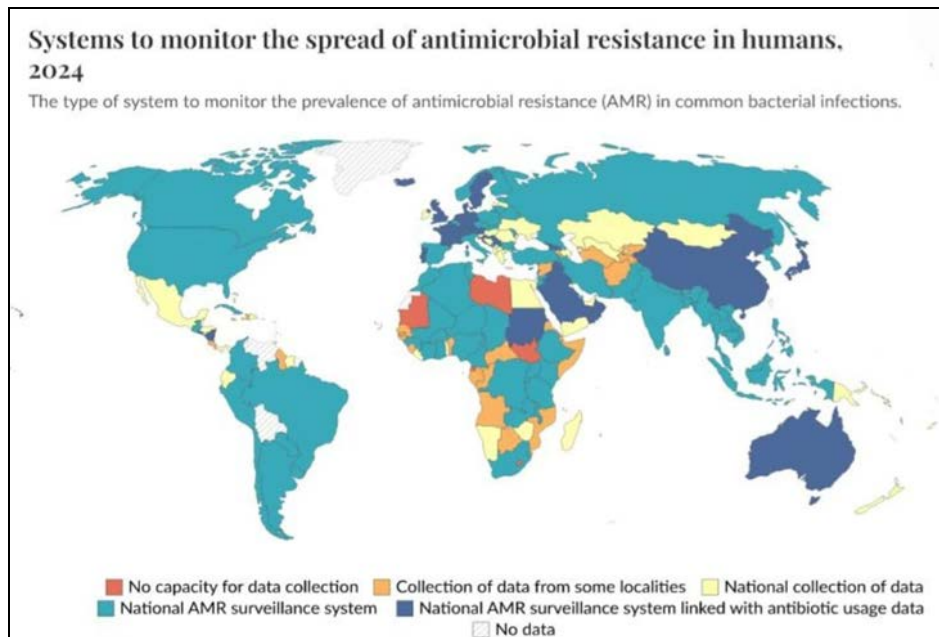


Fig 1

Methods

This review adheres to the SANRA (Scale for the Assessment of Narrative Review Articles) guidelines. A comprehensive literature search was performed in PubMed, Scopus, and Google Scholar for articles published from January 2015 to March 2025. The search strategy utilized a combination of MeSH terms and free text: (“health misinformation” OR “false information” OR “social media” OR “misconception”) AND (“antibiotic” OR “antimicrobial” OR “medication adherence”) AND (“drug resistance” OR “AMR” OR “inappropriate prescribing” OR “self-medication”). Additional grey literature was sourced from WHO, CDC, ECDC, and the Wellcome Trust.

Inclusion criteria: Peer-reviewed original research, systematic reviews, meta-analyses, and case series that specifically investigated misinformation and its impact on medication use behaviour or AMR-related outcomes. Studies from any country and in any language (with English translation) were considered.

Exclusion criteria: Opinion pieces lacking data, studies on medication errors not linked to misinformation, and purely ecological correlations without behavioural measures. Data extraction was carried out using a standardized form that included: source/channel of misinformation, target medication, reported behaviour change, and any microbiological or clinical AMR outcome. Quality assessment was conducted using the Joanna Briggs Institute checklists for observational studies. Thematic synthesis was organized around the mechanisms identified in Section 4.

Sources and Channels of Medication Misinformation

1. Social Media Platforms

Social media has become the leading source of health misinformation. A systematic review by Tang *et al.* (2025)^[17] analysed 624 studies and found that social media hosts a variety of information about AMR and antibiotic use, including a significant amount of false information,⁴ although the exact effect on public behaviour is not fully understood.

TikTok: At the American Academy of Paediatrics 2025^[2] National Conference, a study examined 120 videos with

hashtags like #naturalparenting, #antivaccine, #holistichealth, and #alternativehealing, which collectively garnered over 45 million views. Common themes included substituting antibiotics with herbal remedies and claims that “natural immunity” is superior to vaccination. Notably, 61% of these videos contained misinformation that contradicted AAP and CDC guidelines, and misinformation videos received 2.5 times more views than those based on evidence.

Facebook and WhatsApp: Closed groups and messaging apps are used to share “miracle cures,” photos of leftover antibiotics, and instructions on obtaining them without a prescription. These platforms allow for the swift and targeted spread of misinformation within trusted social circles.

YouTube: Influencers have been documented making claims that antibiotics are “toxic” or that stopping them early “cleanses the body.” A common misconception across platforms is that stopping antibiotics early prevents resistance, which contradicts evidence showing that subtherapeutic exposure promotes resistant mutants.

2. Traditional and Informal Networks

Although digital platforms have accelerated the spread of misinformation, traditional sources still hold sway, especially in areas with low literacy. Family, friends, community healers, and religious leaders continue to influence beliefs about medication. A qualitative study from Iran highlighted the erroneous belief that “for a viral cold, one needs antibiotics. Even if the doctor hasn’t prescribed it, they’ll find a way to get it.”

3. Geographic and Cultural Variations

The content of misinformation varies greatly by region. In South Asia, misinformation often involves self-treating “viral fever” with azithromycin. In Africa, false claims about antimalarials have been reported^[10]. In high-income countries, vaccine misinformation, including false claims linking vaccines to antibiotic resistance, has decreased the uptake of pneumococcal and influenza vaccines, indirectly

increasing antibiotic use. A 2025 [17] report indicates that "better use of vaccines could reduce antibiotic use by as much as a fifth (22%)," yet misinformation continues to hinder vaccination rates.

Region	Common Misinformation Type
South Asia	Azithromycin for "viral fever"
Africa	False claims about antimalarials
High-income countries	Vaccine-AMR false links

Mechanisms Connecting Misinformation to Improper Medication Use

1. Misinformation Specific to Antibiotics

A widespread misconception, perpetuated across various platforms, is that antibiotics can treat viral infections. A comprehensive systematic review and meta-analysis involving 322,492 participants from 98 countries revealed that only 42.1% of people worldwide correctly understood that antibiotics are ineffective against viruses [3]. This understanding was notably lower in countries like Laos (7.2%), Myanmar (11.7%), and Bangladesh (12.5%) [3]. Additionally, just 35.1% of those surveyed were aware that antibiotics do not hasten recovery from colds and flu [3]. Alarming, a 2015 systematic review indicated that 46.1% of the public knew antibiotics don't work against viruses, highlighting that a decade of awareness campaigns has had little effect.

Premature cessation or dose reduction: Misinformation suggesting that completing antibiotic courses "trains bacteria to become resistant" or that antibiotics "permanently harm the microbiome" has led to documented early discontinuation. A 2025 [17] review of antibiotic myths emphasized that "the medical community must critically reassess long-standing clinical practices," [5] and the belief that stopping early is advantageous is a dangerous misconception that needs to be actively countered [18].

Country\Region	% Correct Understanding
Global average	42.1%
Laos	7.2%
Myanmar	11.7%
Bangladesh	12.5%
High-income countries	~60-70%

Sharing and reusing leftover antibiotics: Online forums and social media groups often normalize sharing prescriptions among family members or using previously obtained antibiotics for similar symptoms without consulting a healthcare professional. This practice bypasses professional oversight and results in subtherapeutic, unregulated exposure.

2. Non-Antibiotic Medications

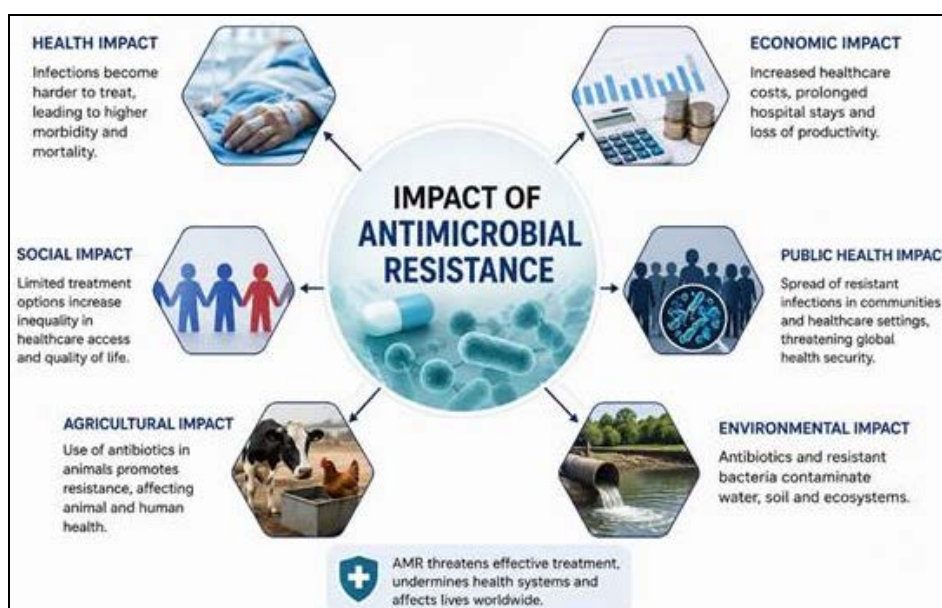
Misinformation about antivirals, antimalarials, and antipyretics can indirectly contribute to AMR. When patients misuse non-antibiotic medications based on false information, they may delay appropriate treatment or develop secondary bacterial infections that require antibiotics. Furthermore, a 2025 [17] Australian study found that common painkillers (ibuprofen and paracetamol), when used with broad-spectrum antibiotics, significantly increased bacterial mutations, making E. coli highly resistant to antibiotics—highlighting how misinformation about over-the-counter medications can have unexpected AMR consequences.

3. Vaccine Misinformation

Vaccines are among the most effective tools for reducing antibiotic use by preventing infections that would otherwise need treatment. False claims that vaccines "weaken the immune system," that "vaccinated individuals shed resistance genes," or that vaccines are generally unsafe have led to reduced coverage [30]. A 2025 analysis suggested that "increasing the coverage of some existing vaccines could prevent 106,000 deaths linked to AMR annually." [9] Conversely, vaccine hesitancy fuelled by misinformation results in more disease outbreaks, increased antibiotic use, and accelerated resistance selection

4. Diagnostic Mistrust

Misinformation suggesting that laboratory cultures are "unreliable" or that "clinical diagnosis is always sufficient" leads to the use of broad-spectrum antibiotics without susceptibility testing. A 2025 [17] review on misdiagnosis in developing countries identified "misclassification of infections—such as viral illnesses mistaken for bacterial infections—and empirical therapy without microbiological confirmation" as key factors driving inappropriate antimicrobial use and the emergence of resistance [11].



Impact on Antimicrobial Resistance

1. Direct Evidence

Subtherapeutic exposure: Misguided beliefs and outdated practices contribute to improper antimicrobial use. Stopping antibiotics too soon, often due to misleading online information, results in drug levels that are too low, promoting the growth of resistant bacterial strains.²⁶ Each unnecessary or incomplete antibiotic course raises the likelihood of resistant mutants developing and spreading.

Overuse and resistance gene enrichment: The widespread misconception that antibiotics can treat viral infections leads to their excessive use.²⁵ A systematic review and meta-analysis from 2025^[43] found that this ongoing misunderstanding will continue to drive the misuse of antibiotics for viral infections,³ a common problem in many parts of the world, thus exacerbating the broader issue of AMR. Ecological data links regional antibiotic use with resistance rates, and overuse fuelled by misinformation directly contributes to this problem.

2. Indirect Evidence

Vaccine refusal due to misinformation: Lower vaccine coverage—whether for influenza, pneumococcus, or other preventable diseases—leads to more bacterial infections that require antibiotic treatment. Each additional infection provides an opportunity for antibiotic use and resistance selection. The 2025^[17] analysis indicating that improved vaccine coverage could prevent over 100,000 AMR-related deaths annually highlights the magnitude of this indirect pathway.⁹

Treatment delays: Misinformation that discourages timely medical care (e.g., claims that antibiotics are “poison” or that “natural immunity” is better) results in the progression of infections. Patients who delay seeking care often present with more severe illnesses, necessitating the use of broader-spectrum, later-line antibiotics (including carbapenems and colistin) where resistance rates are already high.

3. Clinical Outcomes

The ultimate effects include treatment failure, prolonged shedding of resistant organisms, increased hospital transmission, and higher mortality. In hospital settings, patients with resistant infections have a 58% higher adjusted risk of death compared to those with susceptible infections, with the greatest risk associated with bloodstream infections and deaths occurring during the same hospital stay.

Patient-Prescriber Dynamics

The interplay between patient misinformation and clinician prescribing habits is intricate and reciprocal. A study conducted in India in 2025^[7] found that 70% of healthcare professionals prescribed antibiotics instead of the recommended oral rehydration salts for diarrhoea, despite no signs of bacterial infection^[7]. Importantly, the study highlighted that the overprescription was driven by the belief that “patients want antibiotics,” rather than by profit motives or a lack of knowledge^[8]. The researchers noted a “striking disconnect”: clinicians are aware that antibiotics are inappropriate for most diarrhoea cases, yet they prescribe them because they believe parents expect “strong” medications. This issue, known as “defensive prescribing” or “perceived patient demand prescribing,” is worsened by misinformation spread through social media^[7]. When patients come in with expectations shaped by online content, clinicians feel compelled to prescribe even when it is not

medically justified. On the other hand, some patients influenced by anti-antibiotic misinformation may reject even necessary treatments, undermining trust in evidence-based medicine. A 2025 study from Texas created and tested a bilingual educational tool aimed at reducing unwarranted antibiotic expectations, discovering that “patients often expect antibiotics for self-limiting illnesses, pressuring providers to prescribe antibiotics unnecessarily.” These expectations also lead to the dangerous practice of taking antibiotics without a prescription.

Vulnerable Populations and Settings

1. Low- and Middle-Income Countries (LMICs)

LMICs experience the greatest impact of AMR and possess the least robust regulatory frameworks. A study conducted in South Africa in 2025^[2] revealed that 86.67% of individuals in primary healthcare settings had limited health literacy, underscoring how knowledge deficiencies worsen improper antimicrobial usage in resource-constrained areas. In Zimbabwe, only 18.3% of rural households were aware of AMR, illustrating the significant knowledge gaps that allow misinformation to spread unchecked.

2. Rural and Remote Communities

Rural populations encounter two main challenges: restricted access to healthcare and a strong dependence on informal information channels. A 2025^[8] review highlighted that “low-income and middle-income countries are most affected due to inadequate surveillance systems, poor regulation, and limited access to health and veterinary services.” In these environments, misinformation within communities spreads swiftly and is challenging to combat.

3. Elderly Populations

Older adults are increasingly at risk of resistant infections due to factors associated with aging and healthcare exposure. A 2025^[17] study on AMR patterns among older adults in Nepal identified a “high burden of MDROs among older adults, emphasizing the urgent need for targeted antimicrobial stewardship.” A modelling study of European populations indicated that “older people, particularly those aged 74+ and men, face a rapidly increasing risk of resistant infections^[29].” The elderly are especially susceptible to misinformation due to lower digital literacy and greater reliance on traditional media sources that may disseminate outdated or incorrect information.

4. Paediatric Populations

Children are vulnerable because parental misinformation leads to inappropriate antibiotic use for viral fevers. A 2025^[17] systematic review on AMR in enteric pathogens among children aged ≤10 years in LMICs found significant resistance burdens. An Indian study showing that clinicians prescribe antibiotics for paediatric diarrhoea because they believe parents expect “strong medicines”⁷ demonstrates how misinformation about suitable paediatric care results in inappropriate prescribing.

Economic and Public Health Burden

1. Direct Healthcare Costs

The financial impact of AMR is immense. A global assessment revealed that infections resistant to antibiotics are linked to a median hospital cost of US\$693 billion worldwide, with US\$207 billion potentially preventable through vaccination^[29].

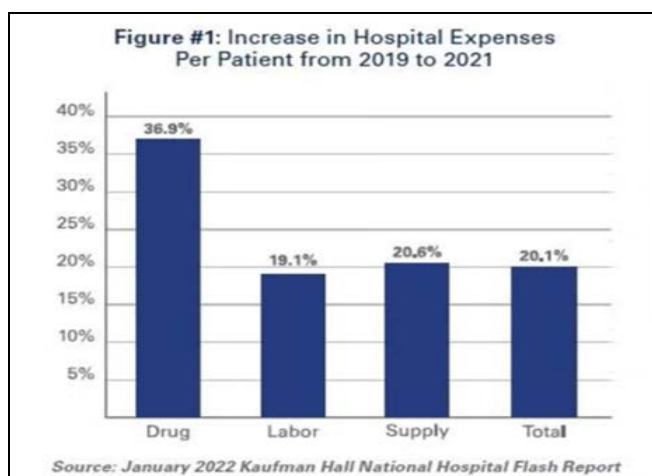


Cost Category	Amount	Source
Median hospital cost (global)	US\$693 billion	2025
Potentially preventable via vaccination	US\$207 billion	2025
Annual European costs (AMR+HAI)	€ billion	ECDC 2025
Projected deaths (2025-2050) ^[41]	39 million	IHME

In Europe, the annual expenses from AMR and healthcare-associated infections surpass €7 billion, and this burden is on the rise^[13].

2. Costs Attributable to Misinformation

Although pinpointing exact figures is difficult, misinformation significantly contributes to these expenses. Every unnecessary antibiotic prescription resulting from patient misinformation leads to wasted healthcare resources, heightened risk of adverse drug events, and accelerated resistance development, which imposes future costs on the entire healthcare system. A 2025^[17] model estimating economic losses due to incorrect microbiological diagnoses and irrational antimicrobial use showed that inappropriate treatments—often fuelled by misinformation—result in considerable direct and indirect economic impacts^[11].



1. Strain on Antimicrobial Stewardship Programmes

Antimicrobial stewardship programmes (ASPs) are increasingly challenged by the need to combat patient misinformation. As highlighted in a 2025^[2] commentary, “misinformation—including chatbot-generated health

advice—is spreading rapidly,” and initial studies indicate that the public may view AI-generated responses as more empathetic than those from healthcare professionals, complicating efforts to provide accurate information. An AHRQ-funded project identified “widespread misconceptions and problematic behaviours regarding nonprescription antibiotics, underscoring the necessity for effective antibiotic stewardship programs.”^[27]

2. Projected Future Burden

The Institute for Health Metrics and Evaluation (IHME) forecasts that 39 million people will succumb to AMR between 2025^[8] and 2050, with annual deaths due to AMR reaching nearly 2 million by 2050. The same analysis suggests that 92 million infectious deaths could be avoided with improved healthcare and antibiotic access^[21], but misinformation-driven misuse directly hinders these potential benefits. Regional disparities are notable, with sub-Saharan Africa and South Asia experiencing disproportionate burdens.

Counter-Strategies and Mitigation

1. Digital Interventions

Pre-bunking (psychological inoculation): Pre-bunking involves presenting individuals with diluted versions of misinformation before they encounter the full-strength false claims, thereby developing “cognitive antibodies” to resist future manipulation^[24]. This method has become increasingly recognized as a proactive way to build resilience against expected misinformation exposure. A 2024 meta-analysis identified pre-bunking as one of the most effective tools for combating misinformation^[24], offering a cost-effective, evidence-based approach.

Debunking and fact-checking: Although not as effective as pre-bunking, correcting misinformation promptly after exposure remains important. Automated fact-checking tools and platform-based labelling systems can help curb the spread of false claims.

AI and Chatbot interventions: Conversational agents can deliver immediate, evidence-based responses to medication inquiries. However, caution is advised: a 2025^[17] analysis highlighted “a lack of standardization in research on using large language models for supporting antibiotic prescribing, necessitating more efforts to identify biases and misinformation in their outputs.”^[14]

2. Healthcare System Responses

Clinician communication training: It is crucial to train clinicians to address misinformation in a respectful and effective manner. Techniques such as motivational interviewing and structured communication protocols (e.g., "Ask, Tell, Ask") can assist clinicians in correcting misconceptions without alienating patients [19].

Integration of AMR and media literacy education: School-based programs that teach critical evaluation of health information and basic principles of antimicrobial use can foster resilience from an early age [20]. The 2025 [2] review on public understanding concluded that "multifaceted strategies are needed to enhance public knowledge of antibiotics [3], including patient education by healthcare professionals, targeted outreach, mass media and digital campaigns, formal education, community-based interventions, robust policy and regulatory measures, and international collaboration."

3. Policy and Regulation

Platform accountability: Social media companies must be held responsible for harmful medication misinformation. China has introduced new regulations requiring internet platforms to verify medical licenses or employment certificates of health content creators, who must be affiliated with recognized medical institutions [15]. A 2025 BMJ editorial argued that "biased or misleading medical advice shared by social media influencers can cause harm and requires coordinated action by governments and platforms to protect the public," recommending "effective regulation, stronger platform and influencer accountability, and user empowerment through targeted education and access to reliable, fact-checked information." **Prescription tracking and public dashboards:** Real-time electronic prescription monitoring, linked to public dashboards displaying local resistance patterns, can empower patients and clinicians to make informed decisions while highlighting the consequences of misuse [28].

Literature Gaps and Directions for Future Research

Despite increasing awareness of the issue, several significant gaps persist:

- 1. Longitudinal research:** There is a scarcity of studies that directly connect individual exposure to misinformation with subsequent medication behaviour and microbiologically confirmed resistance carriage. Most existing evidence is cross-sectional or ecological.
- 2. Randomized controlled trials:** There is a lack of rigorous trials assessing the impact of misinformation-correction interventions on concrete AMR outcomes, such as resistance prevalence and clinical failure rates. Most trials focus only on knowledge or self-reported behaviour changes.
- 3. Comparative cross-country analyses:** Systematic comparisons of misinformation content, analysed through natural language processing, with national AMR surveillance data could help quantify the impacts at the population level.
- 4. Real-time surveillance systems:** Integrating social media trend data, such as spikes in posts about "antibiotics for flu," with prescription databases and

resistance patterns could facilitate early warning systems for emerging misinformation threats [28].

- 5. Implementation research:** Scalable and cost-effective digital interventions for low-resource settings are still underdeveloped. The 2025 [2] South African study, which documented 86.67% marginal health literacy, highlights the urgent need for context-appropriate solutions.

- 6. Economic attribution models:** There is a need for robust models that quantify the economic burden specifically attributable to misinformation-driven inappropriate use, to guide resource allocation for counter-strategies [12].

Discussion

This narrative review compiles evidence indicating that health misinformation significantly influences inappropriate medication use and antimicrobial resistance, which can be modified. Four main mechanisms—overuse of antibiotics for viral infections, early cessation of treatment, vaccine hesitancy, and distrust in diagnostics—each play a role, directly or indirectly, in the emergence and dissemination of resistant organisms.

The persistence of these mechanisms is noteworthy. Despite a decade of global awareness campaigns following the WHO's 2015 [61] declaration of AMR as a top-10 global health threat, the percentage of the public who understand that antibiotics are ineffective against viruses has actually decreased from 46.1% to 42.1% [3]. This indicates that current educational efforts are inadequate to counteract the speed and reach of misinformation on social media [17].

Social media platforms have fundamentally transformed the information landscape. The observation that misinformation videos on TikTok receive 2.5 times more engagement than evidence-based content—a trend consistent across various health domains—illustrates that platform algorithms may unintentionally prioritize sensational, false content over accurate, nuanced information. Addressing this issue requires both technical solutions (algorithmic adjustments) and regulatory oversight.

The patient-prescriber dynamic highlighted by recent studies in India and the US—where clinicians prescribe antibiotics not because they believe they are necessary, but because they perceive patient demand—represents a crucial intervention point. Correcting clinicians' misperceptions about patient expectations, along with directly educating patients, could significantly reduce inappropriate prescribing [7, 31].

Strengths and Limitations: This review is limited by the varied quality of available studies; many are cross-sectional and cannot establish causality. Publication bias may favour studies reporting positive associations between misinformation and harmful outcomes. Most research originates from high-income countries or a limited set of LMICs, limiting generalizability. Additionally, the rapidly evolving digital landscape means that findings may quickly become outdated as new platforms and misinformation tactics emerge.

Nevertheless, the convergence of evidence from behavioural studies, microbiological research, clinical outcomes data, and economic analyses supports a substantial causal role for misinformation in driving AMR. Implications for Policy,

Practice, and Research For policy, social media platforms must adhere to enforceable standards for health information accuracy, especially concerning medication-related content. Platform accountability mechanisms including content moderation, source verification, and algorithmic transparency—are essential.

For clinical practice, every patient interaction is an opportunity to identify and correct misconceptions. Training clinicians in communication strategies to address misinformation should be integrated into medical education and ongoing professional development.

For public health, media literacy education should be incorporated into school curricula and community health programs. Public awareness campaigns should be redesigned to address specific misconceptions identified in the literature, using platforms where misinformation currently thrives.

Conclusion

Health misinformation is not just a minor issue or an annoyance; it is a major, changeable factor contributing to the misuse of medications and the rise of antimicrobial resistance. The pathways are evident: the excessive use of antibiotics for viral infections, driven by persistent misconceptions that have not improved over the past decade; the premature stopping of treatments due to misinformation about the microbiome; vaccine hesitancy, which weakens one of our strongest tools against antimicrobial resistance; and a lack of trust in diagnostics, leading to the empirical use of broad-spectrum antibiotics.

The stakes are enormous. With an estimated 1.14 million deaths each year directly linked to drug-resistant infections, and predictions of 39 million deaths from 2025^[17] to 2050, the human and economic costs of inaction are overwhelming. Misinformation is a factor we can tackle—through digital pre-bunking, training clinicians in communication, regulating platforms, and ongoing public education.

What is required now is a coordinated, multidisciplinary effort involving public health officials, technology companies, healthcare systems, educators, researchers, and policymakers. The time to act is before the next wave of misinformation meets the next resistant pathogen.

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The authors do not have any conflict of interest

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This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement

This study did not involve human participants, and therefore, informed consent was not required.

Clinical Trial Registration

This research does not involve any clinical trials.

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Not Applicable

Author Contribution

Mrunal Santosh Kumavat: Conceptualization, literature review, data collection, manuscript writing, and final editing.

Bhagyshree Nimba Sonawane: Literature search, formatting, proofreading, data organization, and manuscript review.

Rutuja Dnyaneshwar Patil: valuable guidance, continuous support, and encouragement throughout the completion of this review work.

Atul Rupchand Bendale: Constant encouragement, Insightful suggestions, and continuous support throughout the preparation of this review paper.

Anil Govindrao Jadhav: Project administration, Supervision, Final approval of the manuscript

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